AN

# EXPERIMENTAL RESEARCH

TO

# INCREASE THE PROTECTION OF

# SAFES,

AGAINST

# FIRE, DAMPNESS, RUST AND FROST

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BOSTON:

ALFRED MUDGE & SON, PRINTERS, 34 SCHOOL STREET.

1863.

# SAFES

FOR

# BOOKS AND PAPERS.

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What are the requisites of a safe for the preservation of valuable books and papers?

It should be proof against ordinary attempts to break open.

It should provide the largest practicable measure of protection against fire.

It should protect its contents against dampness.

It should be proof against injury by frost.

It should be proof against rust.

It should be as cheap and light as the foregoing requisitions will permit.

The experience of the last few years, has practically demonstrated, what might have been foreseen, that *protection against fire, can be relative only, not absolute.*

Fire proof buildings, so called, yield when stored with combustible materials and for a long time surrounded by flame. The best of fire-proof safes are destroyed, when exposed to heat sufficiently intense and prolonged.

This being admitted, how shall the largest practical measure of protection against fire be secured?

First. By placing the books, papers, etc., to be preserved, in an *incombustible enclosure*, as of iron.

Second. By surrounding the books, etc., by a *non-conductor of heat.*

Third. But chiefly by interposing between the incombustible enclosure or outer iron shell and the wooden case containing the valuables, a substance which on the approach of fire, is *converted into vapor, absorbing the heat and carrying it away.*

If the second and third be omitted, the contents of the safe will be destroyed as soon as the iron enclosure has become sufficiently hot to set them on fire. If the third only has been omitted, the power of preservation will be proportioned to the thickness of the layer of non-conducting material; and this, at the best, is relatively but for a brief period. If the second, only, has been omitted, since the protection arising from vaporization is due to the absorption of heat in converting liquid or solid substances into vapor, it will obviously be proportioned to the quantity of substance so converted into vapor. A hundred pounds of water will absorb twice as much heat in passing off in the form of steam, as fifty pounds will; and a safe that contains one hundred pounds of water to be evaporated, will preserve its contents in safety, through a fire in which a safe containing but fifty pounds would be destroyed.

*A safe will then, manifestly, be a better protection against fire, in proportion as it unites within an incombustible shell, the best non-conductor, with the largest amount of liquid or solid to be converted into vapor, at a temperature not dangerous to the contents of the safe.*

### HOW ARE THE CONTENTS OF A SAFE TO BE PROTECTED AGAINST DAMPNESS?

The injuries from this cause are, not infrequently, of the most serious character. Valuable papers and books become

mildewed, and in time quite disintegrated, from the moisture which condenses upon them. These injuries arise from the evaporation of water from the fire resisting composition, through cracks imperfectly closed at the time of manufacture, or made subsequently by rusting; or by passing through the pores of the wooden case; or by freezing the water of the composition, by the expansion of which the walls are separated from each other and communication established between the filling and the chamber of the safe.

They may be prevented by so constructing the safe as to absolutely prevent any communication of water or vapor between the filling of the safe and the books and papers.

### HOW IS THE SAFE TO BE PROTECTED AGAINST INJURY FROM FREEZING?

In a climate like ours, a safe may be exposed occasionally to temperatures below freezing. Any of the safes as at present constructed, cannot contain any considerable quantity of water above that in chemical combination, without the danger of bursting by cold. This opening of the seams of the safe, at once exposes the contents of the case to the exhalation of moisture from the filling.

The protection against this kind of injury, manifestly lies in such construction of the safe as will provide for the expansion consequent on freezing, without opening the joints or seams of the various parts.

### HOW IS RUSTING TO BE PREVENTED?

This is one of the agencies by which communication between the filling and the chamber of the safe is effected

after the lapse of time; and by which the contents of the chamber become damp.

It may be prevented by consuming the oxygen of the air which would otherwise act on the iron. Chemical compositions are prepared which will, by absorbing the oxygen, perfectly protect the iron from corrosion or rust, even in the presence of air and water.

### DIFFERENT KINDS OF SAFES IN USE.

The safes at present in use differ from each other in various respects, but chiefly in the *capacity of the composition employed, to yield vapor.*

The earlier safes were designed chiefly to protect treasure against burglary, and were distinguished for their strength. Next came safes having non-conducting walls as protection against fire. In 1840, a safe appeared which took advantage of the principle of vaporization of water as protection against fire. The alum safe, upon the same principle, was devised in 1843. The gypsum safe, also on the same principle, has long been in use. The cement safe, in which hydraulic cement is substituted for gypsum, has been many years in use.

In the English safe of Milner, invented in 1840, the space between the iron shell and wooden case is occupied with closed tubes containing water, these tubes being imbedded in saw dust. On exposure to fire the tubes burst and the water, flowing into the saw dust, is converted into vapor, and escapes through the joints of the iron shell.

In the Alum safe, invented by Messrs. Tann, of England, and a modification of which is produced in this country, the vapor is derived from the water of crystalization of the alum.

Twenty per cent. of the weight of the alum is converted into vapor at 212°, and eighteen more at 250°. The remainder is given up only at a heat destructive to the contents of the safe.

In the ordinary gypsum safes, the surplus water added in the mixing, if it does not remain to do injury by charging the case and books with dampness or by freezing, is in process of time exhaled until there remains only what has entered into chemical combination. This latter amounts to twenty per cent. Of this, ten per cent. is given up at 212°, and half of the remainder below 300°.

The cement safes, as they are usually prepared, contain, after setting, and after time for giving up the surplus water, about six per cent. of water. Of this, one per cent. goes out at 212°.*

As the Alum safes are prepared in this country, the alum is mixed with pipe clay, and this mixture with fragments of brick, the former to absorb the water as the alum melts and to facilitate the vaporization; the latter to give support and prevent the composition from falling when the alum melts. The proportion of alum is about one quarter of the whole. This would give of water from the composition, at 212°, only five per cent., and at 250°, four and a half per cent. more, or only nine and a half in all. If the alum were raised to the proportion of one half of the whole mixture it would give up but ten per cent. of water at 212°, and nine more at 250°, or only nineteen per cent. at temperatures not dangerous to the contents of the safe.

In most fires the exposure is for so brief a period that the protection in some of the best safes is adequate; but there

* These numbers will doubtless vary somewhat, according to the cement used.

is the constant possibility that the fire may be too powerful and too protracted for the composition employed, and the protection consequently inadequate.

CAN THE PROTECTION AGAINST FIRE BE INCREASED?

The incombustible inclosure is of wrought iron. Nothing could be better.

What is the best practicable non-conductor?

What is the best composition for keeping down heat by vaporization?

A series of experiments has been made to answer these two inquiries.

In answer to the first question, experiments were made, among other materials, with

| | | | |
|---|---|---|---|
| Infusorial earth, | heated | to | 220°. |
| A mixture of Sal Soda and Gypsum, | " | " | " |
| A mixture of Glaubers Salt and " | " | " | " |
| Set Cement | " | " | " |
| Alum and dry Cement | " | " | " |
| Gypsum with Gelatine | " | " | " |

A wrought iron cup, containing about 8 ounces of water, was filled with each substance in its turn, and the bulb of a thermometer imbedded to the same distance from the bottom in all. The vessel and its contents were then subjected to the same degree of heat. The conducting power, or the facility of heating throughout, was measured by the number of degrees swept over by the ascending column of mercury in successive minutes.

The range of heat was from 220° to 572°.

Infusorial Earth was heated 27° in one minute.

Sal Soda and Gypsum taken in equal parts, 14° in one minute.

Glaubers Salt and Gypsum, taken in equal parts, 12° in one minute.

Cement, set and dried, 11° in one minute.

Potash Alum, 3 oz. / Dry Cement, 6 oz.: 5° per minute, from 220° to 300°. 4° per minute, from 300° to 572°.

Gypsum, 6 oz. and Water, 6 oz. with 3 per cent of Gelatine: 2° per minute, from 220° to 300°. 4° per minute, from 300° to 572°.

From each, the water due to a temperature of 212°, had, as already intimated, been driven out. In the cement, alum, and gypsum, there remained water in combination. The infusorial earth proved the best conductor, and would of course be the poorest substance for filling a safe. Of all, the gypsum and gelatine as prepared for this experiment throughout the range in which the contents of the safe are secure against fire, namely, below 300°, affords the best protection, so far as conduction is concerned.

It is indeed, difficult to conceive of a substance better suited for non-conduction than this mass of set plaster and gelatine, after the surplus water alternating with every particle of gypsum, has been driven out, leaving behind an infinity of minute cavities rendering the whole porous and non-conducting to the last degree.

How shall this quality be combined most advantageously with the second requisite mentioned above, that of supplying matter to be vaporized, thereby carrying the heat away?

## HOW SHALL NON-CONDUCTION AND VAPORIZATION BE BEST UNITED?

Two sets of experiments were undertaken to determine this point. The first on a small scale, the second on a large

and more practical scale. The first was conducted at the same time with the series already detailed, and employing the same apparatus. The wrought iron cup was filled with each mixture in turn, supported at a constant altitude over a flame of uniform height, and the thermometer imbedded to the same depth in all. The readings of the thermometer and watch, were, as a general thing, every minute.

The temperature of 220° has been taken as the limit of the escape of water passing off freely. The results are as follows:

| | | | |
|---|---|---|---|
| Gypsum, 6 oz.; Water 6 oz. with three per cent. gelatine | 45 minutes | from | 212° to 220°. |
| | 23 " | " | 220° to 300°. |
| | In all 68 " | | |
| Cement, 6 oz.; Water, 6 oz. | 42 " | " | 212° to 220°. |
| | 4 " | " | 220° to 300°. |
| | In all 46 " | | |
| Glaubers salt, 5 oz.; Gypsum, 5 oz.; Water, 1 oz. | 32 " | " | 212° to 220°. |
| | 8 " | " | 220° to 300°. |
| | In all 40 " | | |
| Sal Soda, 5 oz.; Gypsum, 5 oz.; Water, 1 oz. | 33 " | " | 212° to 220°. |
| | 5 " | " | 220° to 300°. |
| | In all 38 " | | |
| Alum, 3 oz.; Dried Cement, 6 oz. | 13 " | " | 212° to 220°. |
| | 11 " | " | 220° to 300°. |
| | In all 24 " | | |

A glance at these results will show that the protection afforded by vaporization from 212° to 220°, is pretty nearly in the order and ratio of the relative quantities of water escaping at or below 212°, in the several compositions here employed.

| | |
|---|---|
| Gypsum, gelatine and water had | 6 oz. water. |
| Cement, | 6 oz. " |
| Glaubers salt and gypsum, | 4.2 oz. " |
| Sal Soda and gypsum, | 3.87 oz. " |
| Alum, | .57 oz. " |

The superiority of the first four of the series, is manifestly due solely to the quantity of water they were in condition to give out. Gypsum and cement, as ordinarily set and dried, would have appeared at the bottom of the series. Set gypsum from which the surplus water has evaporated, contains, as already mentioned, but ten per cent of water, that may be driven out at 212°. In the preparation here employed, in which the gelatine is made to increase the capillary power of the gypsum, from three-quarters to four-fifths of the entire space occupied by the set gypsum is water. In the one case one hundred parts contain twenty parts of water, of which ten will go out at 212°. In the other case one hundred parts of gypsum are combined with and enclose one hundred parts of water, of which ninety parts will go out at 212°. At 300° the former will give up fifteen parts and the latter ninety-five.

COMPOSITION YIELDING VAPOR ONLY AT 212° AND ABOVE.

The question of using a composition which should give up vapor at a temperature above 212° only, was tested in the use of a mixture of sulphate of ammonia and common salt

diluted with powdered coke, which on the application of heat, yielded sal ammoniac. Experiments were also made with a mixture of ammonia-alum and common salt, diluted like the above with coke. This yielded water in addition to sal ammoniac. Clay and powdered brick were substituted for coke. They gave results inferior to all except the potash-alum.

In addition to these Laboratory experiments, a series was undertaken on a scale of such magnitude as to render the results of more direct practical value. As the object was to determine the relative excellence of different kinds of safes in which all the circumstances of exposure were the same, it was conducted with great attention to details, and was, on many accounts, the most important ever made of which any record has been preserved.

Through the coöperation of Mr. Anson Hardy, a safe manufacturer, of Boston, and the Messrs. Hinckley, Williams & Co., iron founders, of Boston, the necessary facilities were provided.

### EXPERIMENTS IN REVERBERATORY FURNACES.

Five wrought iron safes were constructed, each of one cubic foot capacity. For each a small wooden box four inches in the clear, and three-quarters of an inch in thickness, was prepared to represent the inside case. When in place, there was a space for composition of three inches thickness on every side of the box. In each wooden box was placed a piece of parchment, some white writing paper, cotton batting, a piece of sealing wax, a self-registering thermometer ranging to 600°, and a series of small thermometers bursting at given temperatures.

| | | |
|---|---|---|
| No. 1 contained | Sulphate of Ammonia, | 15.5 lbs. |
| | Common Salt, | 15.5 " |
| | Powdered Coke, | 24 " |
| | Wooden box, | 2 " |
| | Iron shell, | 27 " |
| | Total, | 84 lbs. |
| No. 2 contained | Potash-alum, | 26 lbs. |
| | Pipe clay, | 26 " |
| | Brick, | 28¾ " |
| | Dry cement to fill, | ¾ " |
| | Wooden box, | 2 " |
| | Iron shell, | 28¾ " |
| | | 112¼ lbs. |
| No. 3 contains | Ammonia-alum, | 26½ lbs. |
| | Common salt, | 13½ " |
| | Coke, | 16 " |
| | Wooden box, | 2 " |
| | Iron shell, | 29¼ " |
| | | 87¼ lbs. |
| No 4 contained | Cement, | 60 lbs. |
| | Water, | 19¾ " |
| | Soapstone front, | 9 " |
| | Wooden box, | 2 " |
| | Iron shell, | 30 " |
| | | 120¾ lbs |
| No. 5 contained | Plaster of Paris, | 50 lbs. |
| | Water, | 21 " |
| | Dry cement to fill, | 9 " |
| | Wooden box, | 2 " |
| | Iron shell, | 28 " |
| | | 110 lbs. |

These safes were carefully introduced into a reverberatory

furnace from which a discharge of twenty thousand pounds of molten iron had just taken place, and when the walls were nearly at the temperature of melted iron. The safes were placed on the bottom of the furnace, the door closed, and after adjusting the draft so as to permit the furnace to cool slowly down in the usual way, the safes were left from five o'clock in the afternoon till ten the next morning.

### RESULTS OF THE EXPERIMENT.

On taking the safes from the furnace they were first weighed.

| | | | | |
|---|---|---|---|---|
| No. 1 | had | lost | $8\frac{1}{4}$ | lbs. |
| No. 2* | " | " | $15\frac{3}{4}$ | " |
| No. 3 | " | " | $16\frac{3}{4}$ | "† |
| No. 4 | " | " | 13 | " |
| No. 5 | " | " | 16 | " |

The temperature of No. 1 had been above 600°. The paper, cotton batting and box were charred; the parchment and sealing wax were destroyed.

The temperature of Number 2 had been as high as 580°. The paper, cotton and box were charred. The parchment and sealing wax were destroyed.

The temperature of No. 3 had been 350°. Contents were much less injured than those of No. 1 and No. 2, but were still greatly discolored. The box was partially charred.

The temperature of No. 4 was 287°. The paper and cotton were discolored. The box thoroughly dried and shrunken somewhat, but not charred. The parchment was shrivelled and the sealing wax melted.

* This is the common Alum safe, except that one-third of alum was employed instead of one-quarter.

† One pound of this and of each of the preceding two, is due to the charring of the wooden box.

The temperature of No. 5 had been 212°. The parchment was somewhat shrivelled and sealing wax melted, but the paper, cotton batting and box were uninjured.

In the safes filled with potash-alum, clay and brick,—with ammonia-alum, salt and coke,—and with sulphate of ammonia, salt and coke, a coarse porous wall around the interior wooden case was preserved after the volatile matters had been driven out.

In the cement safe the cement retained about one-third of its water and the form perfectly.

In the gypsum and water safe the plaster retained its form. It had parted with about four-fifths of its water. (Strictly $\frac{16}{21}$.)

From the foregoing, it is evident that in keeping the temperature down a given time

$7\frac{1}{4}$ lbs. of sal ammoniac are inferior to
$14\frac{3}{4}$ " " water from potash-alum; and these inferior to
$15\frac{3}{4}$ " " water and sal-ammoniac, from ammonia-alum and salt; and these inferior to
13 " " water from the cement safe; and these inferior to
16 " " water from the plaster and water safe.

In the gypsum and water safe, 5 pounds of water were fixed in the setting, and 16 pounds were held by capillary attraction. These 16 were driven out at 212°. There remained five in combination at the close of the experiment to be driven out at the same temperature.

In the cement safe, 6 pounds were fixed in the setting, and $13\frac{3}{4}$ pounds were held by capillary attraction. Of these $13\frac{3}{4}$, 13 were driven out at 212°. There remained but $\frac{3}{4}$ of a pound to be driven out at 212°.

In the Alum safe there were but 8 lbs. expelled at 212°.

In summary—

The gypsum and water safe lost 16 lbs. at 212°.
" cement " " " " 13 " " "
" alum " " 8* " " "

The water remaining to be expelled, at 212°, from the gypsum and water safe, was 5 lbs.

From the cement safe, was $\frac{3}{4}$ lb.
" " alum " " 0.

Not only was there no water to be driven out at 212°, but $6\frac{3}{4}$ lbs. had been driven out at much higher temperatures, the last at 580°.

A cement safe, as ordinarily made, set and dried, of these dimensions, contains a little more than half a pound of water to be driven out at 212°. In a plaster safe, set and dried, there would have been but 5 lbs. to be driven out at 212°. In an ordinary alum safe, there would have been less than eight; while in the gypsum and water safe, as here prepared, there were 21 lbs., which, by the process already described, might have been increased to 50 lbs.

The potash-alum safe lost altogether within $1\frac{1}{4}$ lbs. as much water as the plaster and water safe, but nearly one-half went out at temperatures from 212° to 580°, a range destructive to books and papers. The ammonia-alum and salt safe lost about 20 per cent. more of water and sal ammoniac than the cement safe of water alone, and yet did not afford the same degree of protection, for the cement safe was heated only to 287°†, while the ammonia safe was heated to 350°.

*A part of this loss was evidently due to the moisture in the clay.

†This elevated temperature, while there was still water in the cement, is manifestly due to the conducting power of the soap stone upon which the wooden box rested.

EXPERIMENT IN FURNACE AT WHITE HEAT.

Another experiment was undertaken with four safes of the capacity of one cubic foot each. Each contained a wooden box, enclosing a series of thermometers constructed to burst at given temperatures.

| | | |
|---|---|---|
| No. 1 contained | Cement, | 64 lbs. |
| | Water, | 3¾ " |

This is cement containing the quantity of water which remains after the filling is set and dried.

| | | |
|---|---|---|
| No. 2 contained | Plaster, | 62½ lbs. |
| | Water, | 12 " |

This is a plaster of paris safe, containing twenty-five per cent. more than the quantity of water due to plaster set and dried.

| | | |
|---|---|---|
| No. 3 contained | Alum, | 33 lbs. |
| | Pipe Clay, | 33 " |
| | Brick, | 19½ " |

This safe, with a smaller proportion of alum, is in extensive use in this country.

| | | |
|---|---|---|
| No. 4 contained | Plaster, | 28 lbs. |
| | Gelatine,* | 1½ " |
| | Water, | 43 " |

These safes were placed in the same reverberatory furnace in which the preceding experiment was conducted. There was this difference between the experiments: The first was

* I employ the term Gelatine as expressing in a single word the substance obtained by the action of boiling water from gelatinizalle substances, like sea-weed, of the variety known as Iceland moss, or potato3 starch, or animal membranes, or from other similar vegetable and animal substances.

conducted with a constantly falling temperature. This with a temperature carried from freezing up to a white heat, and there maintained for thirty minutes; and then permitted to cool down.

At the end of the first half hour, Nos. 1 and 2, which were least exposed, were red hot; No. 3 was at low red, and No. 4 was dark.

At forty minutes the condition was the same.

At forty-two minutes, pronounced melting heat, by the workmen, Nos. 1, 2, and 3, were red, but 4 still dark equally

At fifty minutes, No. 4 became low red, and No. 3 was burned through and melted away at points nearest the fire.

At 60 minutes, No. 3 was at a white heat, and No. 4 was red.

This white heat was maintained for thirty minutes, when the furnace was opened and cooled down sufficiently to examine the condition of the safes.

No. 4 was burned so as to crack a little on one side, but was not melted in any part.

No. 3 was melted away from the top, front, and two sides. The side farthest from the fire, and bottom, were alone whole.

No. 2 was scarcely less injured. The melting did not, however, extend so far down the sides.

No. 1, which was further from the fire and sheltered by the other safes, was burned but not melted.

The fire was again raised to the melting point, the furnace closed, and the safes left in this heated chamber, slowly cooling down, from 5 o'clock in the afternoon till 10 o'clock the next morning.

On opening the furnace, the appearances of the safes had not apparently changed since the examination at the close of the

first experiment. The wooden boxes in Nos. 1, 2, and 3, had been destroyed. The temperature in No. 2 had been above 600°, and in Nos. 1 and 3, above 300°, but not to 600°, though probably not far below.

The wooden box in No. 4, was as fresh as when put in. The thermometer bursting at 150° was destroyed, but that bursting at 212°, was sound. The heat had not attained to that of boiling water. It will be borne in mind that No. 1 is the ordinary cement safe, No. 2 is the ordinary plaster of paris safe, No 3 is the alum safe, and No. 4 the new safe. The first three were destroyed, while the temperature in No. 4 was, at the utmost, entirely within the range of safety to the books and papers.

### CONCLUSIONS IN VIEW OF THE FOREGOING EXPERIMENTS.

1st. It is evident that the protection against fire is mainly *proportioned to the quantity of water the safe can give up to be carried away as steam, and not to the non-conducting quality of its filling.*

2d. It is evident, further, that the protection against fire is not simply as the quantity of water that may be present in the composition for filling, but as the quantity of water that may be parted with *unrestrained by chemical affinity, or* WATER AS SUCH. The more powerful the chemical affinity resisting the escape of vapor the more elevated must be the temperature at which it will leave, while the capacity of the escaping vapor to render heat latent or to absorb and carry it away will remain unchanged. The same quantity of water in combination in alum is not so serviceable in keeping down the temperature as when free.

3d. It is evident, further, that while the water in its un-

combined or natural state must constitute a large part of the filling of a safe in order to make its protection against fire, in the highest degree, available, this water must be held in *solid form* so as to give strength to the safe; and the safe must be so constructed as to prevent the water from passing off by leakage, or as vapor to the injury of the books and papers, or to the lessening of the fire proof qualities of the safe; and yet be so constructed as to allow, on the application of high heat, the most free escape of vapor, from those points to which the heat is applied, without endangering the strength of the safe, or driving the vapor into the interior chamber of the safe; and withal so arranged as to permit freezing, without injury to the safe or its contents.

In a safe made in the light of the foregoing experiments, from 70 to 80 per cent. of the space appropriated to filling, was occupied by water, and yet was exposed for a day and two nights to a temperature of zero without injury.

On exposure to fire the water is resolved into vapor first at the outer surface of the filling, and leaves the best non-conductor according to the results of foregoing experiments, (see pages 8 and 9,) between the water which remains and the heated metal of the exterior shell. At length, when all the water has been driven out as vapor, there remains the non-conductor of the whole thickness of the filling, to protect as long as it may, the contents of the case.

## SUMMARY.

The demands for an improved safe have been met as follows:

1. By securely providing for evaporation by exposure to fire, with a given weight of filling, from two to ten times as much available water as is furnished by any safe in use, and gaining thereby a corresponding increase of protection against fire.

2. By securing a better non-conductor, after the water has been driven from the filling, than any hitherto devised.

3. By so constructing the safe as absolutely to prevent any escape of water or vapor from the filling to the interior chamber of the safe, thereby securing the books and papers against dampness.

4. By so constructing the safe as to provide for the expansion of the water consequent on freezing, without opening the joints or seams; thus while making it possible greatly to increase the quantity of water the safe will contain, at the same time securing the safe, primarily against injury from frost, and secondarily from the exhalation of moisture through the openings produced by the frost, causing injury to the contents of the safe.

5. The great excess of water or of protecting power against fire, in the filling employed, allows a reduction of the thickness of the filling. With a reduction of the thickness, there is, with a given exterior, a larger interior space for the contents of the safe. With this reduction in thickness there is also corresponding reduction in the weight of the safe, and if advantage be not taken of the increased space for the case, it may be taken in the diminished size of the shell; and this will be accompanied by reduction in the cost of the safe.

Safes made in accordance with the results of this research, may be seen at the office of the Tremont Safe and Machine Co , No. 32, School St, Boston.